SYSTEM AND METHOD FOR TREATING SKIN

FIELD OF THE INVENTION

This invention relates to methods and systems for treating skin.

BACKGROUND OF THE INVENTION

The term *"target"* is used herein to denote a skin defect such as a vascular
5   lesion, pigmented lesion, acne, unwanted hair or wrinkle. Selective thermal
treatment of skin is commonly used in aesthetic medicine to remove skin targets. In
order to be destroyed, the target must be raised to a temperature of about 70°C
without raising the temperature of the surrounding epidermis or dermis to damaging
levels. The most popular method of thermal skin treatment is selective photo-
10   thermolysis in which light energy produced by a laser or flash lamp is selectively
absorbed by a pigmented portion of the target. However, with this method it is
often not possible to heat the entire target to a temperature necessary for destroying
it without heating the surrounding skin to damaging levels. The main problem is
that the optical contrast between the target and the surrounding skin tissue is not
15   high enough to obtain a significant difference in temperature between the target and
the surrounding skin tissue.

U.S. Patent No. 5,755,753 discloses use of the radio-frequency (RF) range
of electro-magnetic energy for skin tightening, where RF energy is applied to a pre-
cooled skin surface. U.S. Patent No. 5,846,252 discloses treating hairs to reduce
20   their electrical resistance and then applying RF current.

SUMMARY OF THE INVENTION

The present invention is based upon the finding that selective heating of a skin target by RF energy is enhanced if prior to the application of the RF energy the skin is treated to make the temperature of the target (T_t) at least 5 centigrade degrees (5C°) higher than the temperature of the surrounding skin tissue (T_s). The initial temperature gradient (T_t-T_s>5C°) between the target and surrounding tissue may be achieved either by pre-heating the target or pre-cooling the surrounding tissue.

The invention thus provides a system for treating a skin target comprising:

(a)   one or more RF electrodes configured to be attached to the skin, so as to apply an RF current to the skin;

(b)   a temperature effector configured to create a temperature gradient between the target and skin surrounding the target such that the target is at least 5 centigrade degrees warmer than the surrounding skin.

The invention still further provides a method for treating a skin target comprising:

a)   creating a temperature gradient between the target and skin surrounding the target such that the target is at least 5 centigrade degrees warmer than the surrounding skin; and

b)   applying RF energy to the skin.

The system and method of the invention may be used for such skin targets as a vascular lesion, pigmented lesion, hair follicle, wrinkle and acne.

While not wishing to be bound by a particular theory, it is believed that selective thermolysis of a target by RF energy is enhanced when T_t-T_s>5C° due to an increase in the electrical conductivity in the RF range of tissues when the tissue temperature is increased   [Frances A. Duck, Physical Properties of Tissue, a Comprehensive Reference Book, Academic Press, 1990, p.173]. Accordingly, the dependence of the conductivity σ of a tissue on temperature T is given by:

$$\sigma = \sigma_o (1 + \alpha(T - T_o)) \qquad (1)$$

where σ_o is the conductivity at the reference temperature T_0 and α is a constant known as the temperature coefficient.

Heat generation by RF current can be estimated by Joule's Law:

$$H = \sigma E^2 \qquad (2)$$

5   and the change in temperature in the tissue is obtained using the heat conductivity equation:

$$c\rho \frac{\partial T}{\partial t} = H \qquad (3)$$

where c is the heat capacity of the tissue, ρ is the mass density and E is the intensity of the electric field.

10   Inserting Equations 1 and 2 into (3),

$$c\rho \frac{\partial T}{\partial t} = \sigma_o (1 + \alpha(T - T_o)E^2 \qquad (4)$$

Setting $A = \dfrac{\alpha \sigma_o E^2}{c\rho}$ $\qquad (5)$

and integrating Equation 4, the result is

$$T' = T_0 + \frac{e^{At} - 1}{\alpha} + (T_i - T_o)e^{At} \qquad (6)$$

15   where T_i is the initial temperature of the tissue before the application of RF energy, t is the duration of the application of RF energy, and T' is the final temperature of the tissue at the end of the application of RF energy.

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If the initial temperatures of the target and surrounding skin tissue are T_t and T_s respectively (T_t-T_s>0), then Equation 6 becomes for the target:

$$T_t^{'} = T_0 + \frac{e^{At-1}}{\alpha} + (T_{ti} - T_{to})Ae^{it} \tag{7}$$

and for the surrounding skin,

$$T_s^{'} = T_0^{'} + \frac{e^{At} - 1}{\alpha} + (T_{si} - T_o)e^{At} \tag{8}$$

subtracting Equation (8) from Equation (7) yields

$$T_t^{'} - T_s^{'} = (T_{ti} - T_{si})e^{At} \tag{9}$$

where $T_{t_i} - T_{s_i}$ is the initial temperature gradient between the target and the surrounding skin, and $T_t^{'} - T_s^{'}$ is the final temperature gradient. Equation (9) shows that as the RF current is applied, the temperature gradient increases exponentially. Therefore, by creating an initial relatively small temperature gradient $Tt_i - Ts_i$ >5C°, and applying RF energy, a larger temperature gradient is obtained. This allows heating of the target to a sufficiently high temperature to destroy the target without heating the surrounding skin tissues to damaging levels.

Assuming a typical RF fluence (F) in the skin of 20 J/cm^2, $\alpha = 0.03$ (C°)$^{-1}$ and a heat capacitance $c\rho = 3.6$ J/cm^3 $^{\circ}K$, the factor e^{At} in Equation (9) is

$$e^{At} = e^{\frac{\alpha\sigma_o E^2}{c\rho}} = e^{\frac{\alpha Ht}{c\rho}} = e^{0.83} = 2.3$$

Thus, the temperature gradient increases by a factor of about 2.3 during the application of the RF energy.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

5   **Fig. 1** shows a system for heating a skin target and applying RF to an individual in accordance with one embodiment of the invention;

Fig. 2 shows a method for treating skin using the system of Fig. 1;

Fig. 3 shows an applicator with two electrodes, and a light source used in the system of Figure 1.

10   **Fig. 4** shows a system for cooling skin surrounding a target and applying RF energy to an individual in accordance with another embodiment of the invention;

Fig. 5 shows an applicator with two electrodes, and a cooling system used in the system of Fig. 3; and

15   **Fig. 6** shows a method for treating skin using the system of Figs 4 and 5.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figs. 1 and 2, a system for creating a temperature gradient of at least 5C° between a skin target and the surrounding skin, in accordance with the

20   invention is shown. An applicator **703**, to be described in detail below, contains a pair of RF electrodes **401** and **402** and a light source **403**. The applicator **703** is adapted to be applied to the skin of an individual **705** in the region of a target. The applicator **703** is connected to a control unit **701** via a cable **702**. The control unit **701** includes a power source **708**. The power source **708** is connected to an RF

25   generator **715** that is connected to the RF electrodes in the applicator **703** via wires in the cable **702**. The power source **708** is also connected to a light source **403** in the applicator **703** via wires in the cable **702**. The control unit **701** has an input device such as a keypad **710** that allows an operator to input selected values of parameters of the treatment, such as the frequency, pulse duration and intensity of

the RF energy or the wavelength and intensity of the optical energy. The control unit **701** optionally contains a processor **709** for monitoring and controlling various functions of the device. For example, the processor **709** may monitor the electrical impedance between the electrodes in the applicator **703**, and determine the temperature distribution in the vicinity of the target. The processor **709** may also determine the parameters of the treatment based upon the impedance measurements.

Fig. 2 shows the applicator **703** in detail. The applicator contains a pair of electrodes **401** and **402** that apply RF energy to the skin. A light source **403** produces a light spectrum that is delivered to the skin surface by light guide **404**.

In accordance with the method of the invention, the system shown in Fig. 1 is used to first apply optical energy to a target having a diameter for example of 2 mm. A temperature gradient of 5C° could be created if the optical energy has an intensity from about 5 to about 100 Joules/cm^2 and is applied from about 1 to 200 msec.

The parameters of RF energy may have the following exemplary values:

Frequency of the RF energy: from about 300 kHz to about 100 MHz.

Output power of the RF energy: from about 5 to about 200 W.

Duration of the irradiation: from about 1 to about 500 msec.

Pulse repetition rate: from about 0.1 to about 10 pulses per second.

Fig. 3 shows a flow chart for a method of treating skin using the system shown in Figs. 1 and 2. In step **300**, the applicator **703** is applied to the skin of an individual in the region of a target in the skin. In step **310** the light source **403** is activated so that the target is irradiated with optical energy from the light source **403** conducted through the optic fiber **404** to the target so as to heat the target to at least 5C° above the temperature of the surrounding skin. In step **320** the irradiation with optical energy is terminated. RF energy is then applied to the skin (step **330**). Finally, in step **340**, the application of RF energy is terminated.

Referring now to Figs. 4 and 5, a system for creating a temperature gradient between a skin target and the surrounding skin, in accordance with another

embodiment of the invention is shown. An applicator **803**, to be described in detail below, contains a pair of RF electrodes **401** and **402**. The applicator **803** is adapted to be applied to the skin of an individual **805** in the region of a target. The control unit **801** includes a power source **808**. The power source **808** is connected to an RF

5   generator **815** that is connected to the RF electrodes in the applicator **803** via wires in the cable **802**. The control unit **801** controls a refrigeration unit **812** that cools a fluid such as ethanol or water for cooling the applicator **803**. The cooled fluid flows from the refrigeration unit **812** to the applicator via a first tube in the cable **802**, and flows from the applicator **803** back to the refrigeration unit via a second tube in the

10   cable **802** . The control unit **801** has an input device such as a keypad **810** that allows an operator to input selected values of parameters of the treatment, such as the frequency, pulse duration and intensity of the RF energy or the temperature of the coating fluid. The control unit **801** optionally contains a processor **809** for monitoring and controlling various functions of the device. For example, the

15   processor **809** may monitor the electrical impedance between the electrodes in the applicator **803**, and determine the temperature distribution in the vicinity of the target. The processor **809** may also determine the parameters of the treatment based upon the impedance measurements.

Fig. 5 shows the applicator **803** in detail. The applicator contains a pair of

20   electrodes **401** and **402** that apply RF energy to the skin. The housing and electrodes are cooled by fluid cooled by the refrigeration unit **812** that flows in a tube **408** between inlet **405** and outlet **406**. The inlet **405** and the outlet **406** are connected to the refrigeration unit **812** via the first and second tubes in the cable **802**.

25   Fig. 6 shows a flow chart for a method of treating skin using the system shown in Figs. 4 and 5. In step **600**, the applicator **703** is applied to the skin of an individual in the region of a target in the skin. In step **610** cooling system **812** is activated so that the skin surrounding the target is cooled to a temperature at least 5C° below that of the target. RF energy is then applied to the skin (step 620).

30   Finally, in step 630, the application of RF energy is terminated.